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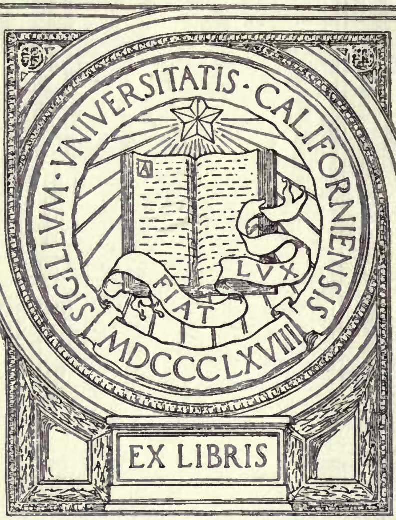

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DEPARTMENT OF THE INTERIOR
WEATHER BUREAU
MANILA CENTRAL OBSERVATORY

THE RETURN OF HALLEY'S COMET AND POPULAR APPREHENSIONS

BY

REV. GEORGE M. ZWACK, S. J.
SECRETARY OF THE WEATHER BUREAU

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LETTER OF TRANSMITTAL.

THE GOVERNMENT OF THE PHILIPPINE ISLANDS,
WEATHER BUREAU,
Manila Observatory, February 4, 1910.

SIR: I have the honor of transmitting a pamphlet entitled "The Return of Halley's Comet and Popular Apprehensions," prepared by Rev. Fr. George M. Zwack, secretary of this Bureau, the publication of which I respectfully recommend.

As the reasons for its preparation are fully stated in the "Introductory Remarks" I need only add that I am convinced that the purpose of its author may be obtained if the pamphlet is given the widest circulation possible.

Very respectfully,

JOSÉ ALGUÉ,
Director of the Weather Bureau.

The honorable,
the SECRETARY OF THE INTERIOR,
Manila, P. I.

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INTRODUCTORY REMARKS.

The present paper on "The Return of Halley's Comet and Popular Apprehensions" is the outcome of a misunderstanding. A short time ago, the writer was requested by the Executive Bureau to furnish some notes on Halley's comet which would help to quiet the fears of such persons as might anticipate trouble from its approach to the earth. After finishing the task in a great hurry, he discovered that all that was wanted were a few statements denying the existence of danger. It seemed, however, to the staff of the Weather Bureau and to other perfectly disinterested persons that the discussion should be published.

It is said that "history repeats itself" and that "superstitions die hard." If this is true, we may look for all kinds of wild rumors circulated by ignorant or malicious persons, setting forth in glowing colors all the horrors which the "comet" is going to bring upon us poor mortals. It is even stated that these irresponsible mischief-makers are already at work in some sections of Manila.

It is believed that the present discussion of these alleged dangers, if given the widest publicity possible, will help in allaying the nightmares of the timid and furnish material to those who desire to dispel the fears of their neighbor.

This paper is not intended as a deep and broad investigation according to the strictest requirements of modern science. Even supposing that the writer were capable of such work, the hurry in which this treatise had to be written would not have permitted elaborate calculations and deep researches. The only claim made for it is that it is a plain and honest exposition of the groundlessness of fear in regard to comets in general, and particularly as concerns the present return of Halley's comet.

THE RETURN OF HALLEY'S COMET AND POPULAR APPREHENSIONS.

By Rev. George M. Zwack, S. J.,
Secretary of the Weather Bureau.

For several months past, scientific and popular periodicals, as well as daily papers, have repeatedly mentioned Halley's comet as due to arrive at its least distance from the earth some time in May of the present year. Though the times are happily past when soothsayers and astrologers, masquerading as astronomers, predicted "hunger, pestilence, and war, the death of mighty princes, and great calamities" whenever a "hairy star" became visible, it nevertheless goes without saying that the comet will strike terror into the hearts of the ignorant, should it become so conspicuous an object in the sky as during former appearances—which it is very likely to do. Moreover, some statements have appeared in print which might cause even otherwise well-informed persons to feel some apprehensions regarding the celestial visitor. Wherefore, it seemed desirable to the writer to thrash out the whole subject of danger from comets, and he promises to "tell the truth, the whole truth, and nothing but the truth"—at least to the best of his knowledge—without minimizing any real danger which might lurk in the return of Halley's comet, for the sake of allaying popular fears.

Now, Is there any reason for uneasiness on account of Halley's comet? Most certainly no! Fear in this case can only be the result of ignorance or superstition, or of both combined. Neither of these is very commendable, either singly or combined, aside from the fact that superstition is sinful.

The only possible reasons for fear could, as far as I can see, be one or several of the following: The comet might be a sign of God's wrath and hence presage impending calamity; or it might have itself some evil influence on our earth; or, finally, might it not fall into the sun and cause us to be roasted alive, or worse still, collide with the earth and precipitate doomsday? But the first and second reasons are unreasonable in case of all comets; the third and fourth at least do not apply to the present return of Halley's comet, though there is no denying that such things could happen under different conditions. Let us examine each of these reasons for anxiety!

I. The first cause of fear stated we must dismiss as superstitious. Comets are *not* signs of God's anger; they are not the fiery rod of the Almighty stretched forth over his naughty children as a warning of coming chastisement. Nor are they some kind of uncanny beings, bent on evil, which God permits to hold sway for our punishment.

No doubt, comets are strange looking affairs. As seen with the naked eye, a large comet usually appears like a dim star surrounded by a patch of more or less luminous nebulosity, which latter seems to stream out in the direction away from the sun, forming one or more tails, some of which have been known to stretch over 35 to 60° of the sky. The bright, star-like point, which on an average is present in four out of every five comets, is called the "nucleus" (Latin word, meaning kernel) and the surrounding nebulosity "coma," being the Latin word for hair. The word "comet," however, is not derived from the Latin, but from the Greek "kometes" which means a person or thing with long hair.

Not less bewildering is their behavior. While the fixed stars are, to all intents and purposes, immovable and the planets move all in one direction around the sun and never depart far from the ecliptic, the greatest inclination known being that of the small planet "Eros" (10° 50′); the comets apparently observe no law; they move direct or retrograde, and the inclination of their orbits to the ecliptic may have every value between 0° and ±90°.

Nevertheless, telescope and spectroscope, with the aid of mathematics, have proved beyond the possibility of a doubt that, all their peculiarities notwithstanding, comets are celestial bodies which do not differ essentially from the sun and the planets, our earth included; that they are composed of matter such as we are accustomed to; and that they follow the universal law of gravitation and other physical laws, as it behooves a somewhat eccentric but orderly member of star society. Nor are they new creations when they appear to us, be it even for the first time; they have wandered through space for ages. Halley's comet in particular is an old acquaintance of the human race, nay, a member of our own planetary family, since it is a *periodic* comet—that is, a comet which revolves around the sun like the earth and the other planets of our solar system—and, therefore, becomes visible at stated intervals. The fact that its path is very eccentric and of vastly greater length than that of our earth and that, consequently, the comet needs over seventy-six years to complete it once, while the earth needs only one, does not alter the truth that the comet belongs to our solar system; that is, to the group of cosmical bodies which revolve around our sun.

But Halley's comet is not the only representative of its class in the sun's family. About seventy-five comets are known to move in elliptical orbits around our central luminary and, while some fifteen of these have periods of revolution exceeding one hundred years, some twenty others have already been observed at more than one return. But besides these seventy-five belonging to the sun's retinue, there is a vast number of comets which come into view only once, because their orbits are parabolic or hyperbolic; that is, they are curves whose branches separate farther and farther. These celestial wanderers come from interstellar space and whisk around the sun with so tremendous a speed that their momentum carries them again beyond the controlling force of our central body, wherefore they pass out again into boundless space until they fall under the dominating influence of some other sun, when they repeat the same performance, until they are caught in some solar system and thenceforth are members of it.

The foregoing exposition makes it clear that comets are by no means warnings of impending calamities, but very natural phenomena. Great disasters have doubtlessly followed the appearances of comets; but the reasoning *"post hoc, ergo propter hoc"* (*after* it, therefore *on account* of it) is exceedingly illogical. The comet had as little to do with them as your or my sneezing on December 27, 1908, had to do with the Calabrian earthquake of the following day.

II. But granted that comets are neither evil beings in themselves nor harbingers of coming chastisement, may they not, in a merely natural way, affect conditions of life on earth and thus cause harm? To answer this question we may consult experience and science. Both deny it emphatically.

1. What does experience teach? The number of comets which visit our solar system is much larger than is ordinarily supposed. Of course, prior to the invention of the telescope in the beginning of the seventeenth century, only those have been noticed which attained a brightness equal at least to a star of the sixth magnitude. Hence we find only about 400 comets recorded from the earliest times down to the year 1600. Since then some 300 more have been discovered, of which number only about one-fifth were visible to the naked eye. As many as eight have been found in a single year (five in the year 1909). There are in fact not many days on which one or more can not be seen by means of modern powerful instruments. Naturally enough, very conspicuous specimens, such as the comet which appeared in 1858 and the great comet of 1882, are not very frequent; nor are these usually the ones which approach closest to the earth. But several comets have already come near enough to warrant our speaking of "experience." Now, while these comets had their periods of revolution changed by the attraction of the earth by amounts measured by weeks, no influence of theirs was noticed. The closest approach was probably that of Lexell's comet in 1770 which came within 1,520,000 miles of the earth. But even in this case not the least harmful effect, nor in fact any effect, could be detected. Why, therefore, should Halley's comet behave differently?

2. But science assures us that it *can not* behave differently. No

harm to the earth or its inhabitants can possibly result from any comet ever observed, except through collision, which we will discuss later on. What could such evil effects be? They would have to consist either in an alteration of the earth's path around the sun, or in the streaming into our atmosphere of noxious matter, or in the setting afire of it by the comet's tail. None of these occurrences is to be feared.

(*a*) As to the first, comets are indeed exceedingly large, but, considering their bulk, also exceedingly flimsy creatures. Thus the head of Enke's comet (period three and three-tenths years) has a diameter of 300,000 miles when it first becomes visible at a distance of 130 millions of miles. This gradually diminishes as the comet approaches the sun; but even so, at a perihelion distance of 33 millions of miles the head has still a diameter of 12,000 to 14,000 miles. Now Enke's comet is by no means a large one. Of still vaster dimensions are the tails with which comets are ornamented while in the neighborhood of the sun. These are rarely less than 10 millions of miles long, but may reach much greater lengths. Thus the tail of the great comet of 1882 was 100 million miles long, 200,000 miles in diameter near the head, and 10 million miles near the end. Such incomprehensibly bulky affairs appear very formidable if we compare them with our little earth of only 8,000 miles in diameter, and they would be, if they were as solid as the earth. But they are not! As stated, several comets came so near to the earth that they had their periods altered by several weeks by the attraction of the latter; but the earth's period—that is, the year—was not affected by the action of the comet even to the amount of a second. Since attraction is mutual, if the immense bulk of the comet had contained only so much matter that one hundred thousand comets would weigh as much as the earth ($\frac{1}{100000}$), the effect of its attraction upon the motion of the earth would have been very appreciable. As in no instance any influence could be detected, no one of these comets can have weighed even one two-hundred-fifty-thousandth part ($\frac{1}{250000}$) of the earth.

Thus a comet 40,000 miles in diameter would probably have a *mean* density of a little less than one nine-thousandth ($\frac{1}{9000}$) of that of air at the earth's surface, or much less than has the residual air in a vacuum tube exhausted by the best air pump.

The orbits of other comets have been greatly altered by the huge planets Jupiter and Saturn, but not the slightest effect upon the motion of the latter has ever been observed. Nay, even their satellites showed no perturbation.

Hence there is no danger of our earth's ever being thrown into new and disastrous paths by the action of a comet.

(*b*) But might not some harmful matter stream into our atmosphere and suffocate every living creature on earth? or set it on fire? As regards Halley's comet, its closest approach to the earth, on May 19, 1910, will be 13,000,000 miles. As far as the head is concerned, this is a very safe distance; but we have to reckon with the tail. Rev. Searle, C. S. P., of Washington, D. C., has figured out that on May 19 of the present year, our earth will probably come within the tail of Halley's comet. As at that time the tail will point in our direction, will possibly be several times the length of the comet's distance from the earth and, maybe, a few millions of miles in diameter, it is almost certain that we will get mixed up in it, unless indeed its curvature be such as to cause it to clear the earth. Dreadful prospect, is it not? Well, as far as the writer is concerned, he devoutly wishes that we may get into it as far as we can, his only fear being that neither he nor anybody else in the Philippines will be aware of the fact that a comet's tail is sweeping over us, unless his suggestion be carried out that self-registering magnetic and electrical instruments be mounted in a suitable place, for instance at Mirador Observatory, Baguio, and continuous observations made from May 15 to 21.

In order to understand why there is nothing to be feared from an encounter between the earth and a comet's tail, we have to say something about the constitution of comets, or rather discuss several hypotheses, because, to tell the truth, nobody knows with certainty in what state of aggregation cometary matter exists.

This may sound very strange to the reader who remembers the statement about the mean density of a comet being less than that in a vacuum tube, but he will please also kindly remember that I said "mean" density. Hence the nucleus may consist of a huge swarm of meteors, 100 to 8,000 miles in diameter, and the individual meteors may vary in diameter from several feet to mere particles of dust: all that is required is that either they are sufficiently far apart, or that the density in other parts of the comet is so exceedingly small that the mean density of the whole is equal to, or less than, one nine-thousandth of the density of air at the earth's surface.

However, whatever may be the state of aggregation in a comet, one thing is sure; comets *as a whole* are not luminous by incandescence. That their light depends in some manner or other on the sun is shown by the fact that on receding from it they disappear on account of *faintness,* while still presenting a measurable diameter. This would be utterly impossible if they were self-luminous in the strict sense of the word. As to their light, the spectroscope tells us that a part of it is reflected sunlight. But the greater part of it gives an emission spectrum which reveals the presence of some gaseous carbon compound, which may be cyanogen or some hydrocarbon, if not both. That the gas is glowing throughout the comet, no scientist will dare assert. Its luminosity is probably due to phosphorescence caused by sunlight; but by far the most probable hypothesis makes it an electrical phenomenon. In speaking of incandescence, the writer was careful to limit the denial to the comet "as a whole"; because when a comet approaches very close to the sun, the gases and even the meteors which are supposed to constitute the nucleus may become heated to such an extent as to become self-luminous for a short time. This explains why the spectrum of the great comet of 1882, which latter passed within 300,000 miles of the surface of the sun (perihelion distance 0.008) showed, besides the carbon bands, also the bright lines due to the vapors of sodium and magnesium, with a multitude of others belonging probably to iron, though the phenomenon did not last long enough to identify the latter.

These facts make it self-evident that there can be no danger of the comet's tail setting fire to the earth or its atmosphere—even if the comet's head consisted of glowing gases at the time of perihelion passage, and these gases streamed out in the tail—first, because they would be cooled down very much by expansion before they reached us; and secondly, because the small quantity encountered by the earth could do it no harm, even if it were incandescent. But the present comet will never get even as close as 54,000,000 miles to the surface of the sun (perihelion distance 0.589), and as its nearest approach to the earth will take place a full month after perihelion passage, still less is to be feared.

But what about the gases constituting the tail and their effect upon life? It was mentioned as probable that cyanogen forms a constituent part of comets. Now cyanogen (C_2N_2) is a poisonous gas! This looks serious enough; but happily it is by no means as bad as it appears. Assuming, but not granting, that the tail is formed of gas, or other *ponderable* matter ejected by the head, some cyanogen, if such is present, would no doubt be picked up by the earth and remain in the atmosphere. But at a distance of 13,000,000 miles this could not possibly amount to one one-hundred-millionth part of the comet. Now, as the whole comet is in mass perhaps equal to our atmosphere, the quantity thus entering the latter would be far less than 0.00000001 of 1 per cent. One hundred thousand times this amount would be absolutely harmless, no matter what the gas might be.

But then the tail is most probably not at all composed of ponderable matter, but merely an electrical phenomenon, similar to the cathode rays seen in a vacuum tube through which passes an electrical discharge.* For this assumption speak, first, the fact that the tail always points away from the sun, as if repulsed by it; secondly, the striking similarity between the telescopic appearance of comets' tails and the phenomena of an electric discharge through a vacuum; thirdly, and above all, the consideration that, if the tail really consisted of gas or dust thrown off by the comet under the repellant action of the sun, the comet would very soon be dispersed through the universe. As the tail points always away from the sun, its end would have to move much faster than the head in order to retain the indicated position. But it is utterly impossible that separate particles some millions of miles farther from the sun than the head should have a greater orbital velocity than the latter! Hence, at every return of the comet to the neighborhood of the sun its substance would he strewn along its path at a rate which no comet could afford very long, especially as no considerable part of it could ever be regained even by periodic comets, and none at all by the others. Moving almost radially to the orbit of the comet, the matter thus thrown off would be far from the comet's path by the time when the latter returns again to the same region of space. As one of the periodic comets comes to perihelion once in every 3.3 years and twelve in periods ranging from 5.2 to 7.6 years, the effect of such throwing-off of matter should gradually become noticeable.

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* The writer is fully aware that the negatively charged particles constituting the β-rays have also a mass (0.0005 of an atom of hydrogen). The expression "ponderable matter" is used merely to obviate the necessity of unwieldy circumlocutions. Moreover, he by no means asserts that the tails of comets *are* β-rays, especially as this would merely *put off* the ultimate dispersion (though many thousand times farther than the other hypothesis), not to mention other difficulties which would arise from the assumption of identity. The cathode rays are used as a familiar *simile;* nothing more.

However, the argument best calculated to dispel all apprehensions regarding the passage through a comet's tail consists in the fact that the thing has actually happened less than half a century ago. According to several astronomers of repute the earth traversed the tail of the great comet of 1861 at 6 o'clock and 12 minutes a. m. of June 30, 1861, some 300,000 miles within it and approximately two-thirds of its entire length from the head. Nothing was noticed except a faint luminosity resembling the zodiacal light, which was seen in the evening of that day.

From all these considerations we must conclude that, whatever may be the nature of the tail of Halley's comet, the passage of our earth through the same on May 19, 1910, will be a very interesting and equally harmless occurrence.

III. From data interspersed in the foregoing explanations it is perfectly clear that Halley's comet, at least at its present return, can not possibly do any mischief by either tumbling into the sun or colliding with the earth. Its *least* distance from the former will exceed 54,000,000 miles; from the latter it will be 13,000,000. As comets have passed unscathed so close as 750,000 miles from the sun, there can be no danger of the present one's falling into it; still less fear—if possible—need there be of its crashing into the earth.

With this remark we might dismiss the question of danger from comets. But we promised to tell the *whole* truth. Now, although Halley's comet is perfectly harmless in every respect, the same can not be said of comets in general, at least as far as regards collisions with the sun or our earth.

1. As to falling into the sun, no one of the periodic comets is likely ever to become dangerous, except "Enke's comet." The period of this small comet (3.303 years) is continually shortening, first by 2.5 hours per revolution, but since 1868 by only about half this amount. If this state of affairs continues indefinitely, the comet will finally fall into the sun. But no one living at present need have any concern about it, nor any of those to come for the next 4,500 years; because, if the acceleration continues at the present rate, the comet's perihelion distance will even then be still about ten times that at which the great comet of 1882 passed in safety: a fair margin even if we take into account the smaller velocity of Enke's comet.

It is, however, somewhat different with the nonperiodic comets. Though exceedingly improbable, it is absolutely possible, that some fine day one of these wanderers enters into the solar system so accurately aimed that by the time it gets into the vicinity of the central luminary, its orbit falls closer to the latter's center than the sum of the radii of sun and comet, or even that they meet on the line of their centers. There would be an awful crash! What would be the outcome? Nobody can tell. The late Prof. Charles A. Young, whose "General Astronomy" is unsurpassed for clearness, has to say the following on this subject:

"If a comet actually strikes the sun, it is not likely that the least harm will be done. If a comet having a mass equal to one one-hundred-thousandth of the earth's mass were to strike the sun's surface with the parabolic velocity of nearly 400 miles a second, it would generate about as much heat as the sun radiates in eight or nine hours. If this were all instantly effective in producing increased radiation at the sun's surface (increasing it, say eightfold, for even a single hour), mischief would follow, of course. But it is almost certain that nothing of the sort would happen. The cometary particles would pierce the photosphere, and liberate their heat mostly *below the solar surface,* simply expanding, by some slight amount, the sun's diameter, and so adding to its store of potential energy about as much as it ordinarily expends in a few hours. There might, and very likely would, be a flash of some kind at the solar surface, as the shower of cometary particles struck it, but probably nothing that the astronomer would not take delight in watching."

2. As to the possibility of a collision between a comet and the earth, the chances are even less than of a comet falling into the sun, as regards the comets which move in nonelliptical orbits, since the diameter of the earth is less than 0.01 of that of the sun.

Matters are, however, vastly different with the periodic comets. The orbits of several of the latter pass closer to the earth's path than the semidiameter of their heads. Therefore, provided both the earth and the comet last long enough, the two bodies are bound to come together.

But such encounters are extremely rare occurrences. Babinet estimates that their likelihood is about one in every 15,000,000 years. As such an event could, and would, be predicted by astronomers months, and perhaps years, in advance, this possibility needs not rob us of a minute's sleep until they sound the alarm.

In speaking of the possibility of a collision of the earth with a comet, the caution was added "provided both the earth *and* the comet last long enough." This reservation was suggested by the history of a comet discovered in 1826 by Biela and hence called "Biela's comet." It *was* a small comet with a period of 6.6 years. Its orbit comes within a few thousand miles of that of the earth, the nearness varying somewhat on account of the perturbations which the comet suffered during its wanderings through the solar system. On several occasions the two orbits approached so closely that, had the earth and the comet arrived simultaneously at the point of least distance, the former would have passed through the outer portion of the comet's head. At the time of the comet's first return after discovery, in 1832, there was a great scare among the inhabitants of southern France, due to a false rumor of an impending collision. In reality earth and comet never came closer together than 15,000,000 miles, since the latter had passed the critical point about a month before the earth arrived there. On its third return, in 1846, the comet divided into two while in full view. When the twin comets were seen again in 1852 they had separated from each other about 1,500,000 miles. Since then nothing has ever been seen of them, though they should in the meanwhile have reappeared no less than eight times, and repeatedly under favorable conditions of visibility! On the night of November 27, 1872, while the earth was passing the old path of the lost comet, she encountered a most magnificent display of meteors. The same phenomenon was repeated, though with less splendor, on similar occasions in 1885 and 1892. In this case, a collision was averted by the fact that the *comet failed to last long enough!*

But suppose a comet *does* collide with the earth! What will happen? No mortal knows, and the writer is not anxious to find out by his own experience. All would depend upon the mass of the comet, the state of aggregation of its matter, the velocity with which the two bodies came together, and the angle of impact. Matters would likewise differ greatly accordingly as the blow would be central or glancing. As it is not feasible to discuss all the possible cases, we will take the most serious, which undoubtedly would be a central collision with both bodies moving in the same or in opposite directions.*

The gaseous constituents of the comet's head would probably be stopped by the resistance of our atmosphere before penetrating very far into it. But, as thereby their motion would be converted into heat, they might possibly make it uncomfortably warm for us. But as their density is so very small and only a minute fraction of the comet's mass could come into contact with our diminutive earth, the effect might, after all, be not very disastrous.

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* Whether there is any probability that the angle between the directions of the two motions would (or even could) be absolutely zero, is a debatable question. As regards the following conclusions, the introduction of a small angle would only complicate calculations without materially affecting the results.

The same, however, can not be said of the smashing into the nucleus. Suppose the latter had a mass equal to only one five-hundred-thousandth part of the earth's mass. This is relatively so small that 6,130 comets could be made out of our little moon. Nevertheless it would be equivalent to an iron ball nearly 84.5 miles in diameter, weighing something like 12,000,000 tons. Since the comet would hardly have a velocity of less than 26 miles per second, matters would be bad enough, even in the most favorable case—that is, if the comet would overtake the earth—as the latter's mean orbital velocity is only 18.5 miles per second. Thus the comet would crash into us with a velocity of 7.5 miles per second. In order to get at least some idea of what this would mean, let us make a comparison:

A shell weighing half a ton fired from a United States 13-inch gun (1898) with a velocity of only 2,100 feet per second, penetrates a plate of solid steel (not armor!) 27 inches thick, if the latter is placed close to the muzzle of the gun. The energy of the projectile works out to be 1,102,500 tons. The effect of the same shell coming with a velocity of 7.5 miles per second, would be 355 times as great, and if the projectile had the supposed weight of the comet's nucleus, its striking energy would be more than 8,600,000,000 tons. Of course, the writer knows that cometary nuclei can not be solid, were it only for the fact that they expand and contract by thousands of miles, as is the case in Enke's comet; but the combined energy of the meteors forming it would be diminished only by the amount to be deducted on account of the increased friction in our atmosphere due to a greater surface presented by innumerable small particless instead of that of a solid ball having the same aggregate mass. What the mechanical effect of such bombardment would be nobody can foretell. Nor would it matter much, because the heat generated by the impact, if expressed in "calories,"* would have to be written: 21,053 followed by seventeen zeros! This quantity of heat would be sufficient to raise the temperature of more than 5,000,000 cubic miles of water from the freezing to the boiling point, an amount of water which could cover the whole surface of the earth to a depth of 84.5 feet. No living being would survive the corresponding rise in temperature.

But results would be vastly worse if earth and comet would come together on their center line, moving in opposite directions. In this case they would collide with a velocity of 44.5 miles per second, and as the striking energy increases with the square of the velocity, the effects of a head-on collision compared with those of a rear collision would be as 44.5^2 to 7.5^2, that is about thirty-six times more serious. In view of these figures, such questions as whether the attraction of the comet would cause a disastrous flood prior to the collision, or what would be the composition of the atmosphere after the event, etc., have little significance. A head-on collision would simply mean the end of the world as far as the human race is concerned.

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* A "calorie" is the amount of energy required to raise the temperature of 1 kilogram of water (2.2 pounds) 1° centigrade (1.8° F.).

Now, what are the chances of so terrible a catastrophe? As stated before, it is bound to happen, provided the earth lasts long enough and comets do not become extinct. As to each individual comet striking the earth, the chances are, according to Arago, as 1 to 281,000,000. There need, therefore, be no more fear of such collision than of the end of the world in general. The latter has been prophesied by our Divine Lord, and its coming is infinitely more certain than a comet's smashing into the earth, still nobody seems to worry very much about it. And indeed, why should we worry concerning the end of the world, knowing, as we do, that for each one of us individually the moment of our death will be the end of the visible world for us. Why fear a comet, when we know that it takes infinitely less to snuff out the candle of our life than a collision between the earth and a comet? It would be infinitely better to be always prepared to die, than to be afraid of it, and for the rest trust in God, without whose knowledge and consent no harm can befall either the whole earth or the lowliest of its inhabitants.

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APPENDIX.

SOME DATA REGARDING HALLEY'S COMET.

As a few data regarding Halley's comet will probably be welcome to many readers, they are added as an appendix.

"Halley's comet" received its name in honor of the famous English astronomer Edmund Halley (1656–1742), who, at the time of its appearance in 1682, calculated its orbit and, after establishing its identity with the comets of 1531 and 1607, pronounced it to be a periodic comet, predicting its return for 1759, or the end of 1758. The prediction came true. The comet passed perihelion on March 13, 1759, only thirty-two days earlier than had been computed by the French mathematician and astronomer Clairaut. Though Halley had died in 1742, posterity did not forget his claim on the comet, which was thenceforth called "Halley's comet."

Two English astronomers of the present time, Messrs. Cowell and Crommelin, have, by patient research and laborious calculations, traced the history of our comet as far back as the year 87 B. C. For every one of the twenty-five returns postulated by the period of the comet since 87 B. C., they found historical proofs. Their dates are as follows:

Year.	Perihelion passage.	Year.	Perihelion passage.	Year.	Perihelion passage.
87 B. C	Aug. 15	607 A. D	Mar. 2	1301 A. D	Oct. 23
12 B. C	Oct. 8	684 A. D	Nov. 26	1378 A. D	Nov. 9
66 A. D	Jan. 26	760 A. D	June 15	1456 A. D	June 8
141 A. D	Mar. 25	837 A. D	Feb. 25	1531 A. D	Aug. 26
218 A. D	Apr. 6	912 A. D	July 19	1607 A. D	Oct. 27
295 A. D	Apr. 7	989 A. D	Oct. 9	1682 A. D	Sept. 15
373 A. D	Nov. 7	1066 A. D	Mar. 27	1759 A. D	Mar. 13
451 A. D	July 3	1145 A. D	Apr. 6	1835 A. D	Nov. 16
530 A. D	Nov. 15	1222 A. D	Sept. 10	1910 A. D	Apr. 19

The present appearance is, therefore, the twenty-seventh of which we have certain knowledge. There can be no doubt that the history of the comet could be traced much farther back by means of the cuneiform inscriptions of Assyria, but this difficult piece of work seems to have not yet been attempted.

While the mean period of Halley's comet as given in astronomical books is 76.37 years, the shortest interval between two successive perihelion passages has hitherto been 74.88 years (1607–1682) and the longest 79.37 years (451–530). All records will, however, be broken by the present visit of the comet. If it passes perihelion on April 19, 1910, only 74 years and 155 days will have elapsed since its passage in 1835! These inequalities are due to the perturbations in the comet's motion caused by the attraction of the planets, especially of Jupiter and Saturn.

At *perihelion* (point of least distance from the sun) Halley's comet is, on the average, only 54,000,000 miles from the center of the sun, while at *aphelion* (point of greatest distance) it is 35.4 times as far as the mean distance between earth and sun, or, in round figures, 3,288,000,000 miles, which is about 496.4 million miles—or more than five times the distance between sun and earth—beyond the orbit of Neptune, the farthest *known* planet.

At its present return, the comet was first discovered by Doctor Wolf, director of the astrophysical observatory on the Königstuhl near Heidelberg, Germany. Two photographic plates exposed to the computed place of the comet in the morning of September 11, 1909, showed the visitor. On the following day Lick Observatory, California, and Helwan Observatory, Egypt, likewise obtained photographs of the comet, which was then too faint an object to be visible, even in the largest telescopes. On September 15, however, it was for the first time observed visually with the 40-inch refractor of Yerkes Observatory, Wisconsin, by Professor Burnham, as a very faint object. Since then it has slowly grown brighter, at times more rapidly than was anticipated.

Several authorities were of the opinion that the comet could be seen by means of field-glasses about the beginning of February, if not earlier. This appears to be not the case. At Manila Observatory the comet was first seen with the 19-inch equatorial on November 25, 1909. It was again picked up in the same telescope in the evening of January 29 and 30. On the latter occasion it was a relatively easy object with the 5-inch finder attached to the larger instrument, but appeared to be below tenth magnitude.

In view of these facts, the reader will probably not be too much surprised if, on reading the following statements concerning the phenomena to be expected, he finds only vague language. Astronomical positions are expected to be given at least down to minutes of arc, and the moment of a celestial occurrence to fractions of a minute of time. He may remember the story of the discovery of Neptune. Though this planet had never been seen *consciously* by human eyes (it had indeed been observed repeatedly, but always been mistaken for a star of ninth magnitude), its existence was deduced from the small differences between the computed and observed places of the planet Uranus. From these perturbations the French mathematician Leverrier calculated the whereabouts of an unknown disturbing planet so accurately that Galle, at Berlin, found the latter on the night of September 23, 1846, within half an hour after commencing the search and only 51′ (a little more than 1.5 times the angular diameter of the sun) from the indicated place. But the same methods and the same genius applied to the computation of cometary motion are far from giving equally good results. Suffice it to mention only that the position of the center of mass of a comet can not be determined as accurately as that of a planet, and of the mass of a comet we know practically nothing. Of a few of them, such as have come sufficiently close to the earth, we know a limit which their mass can not reach, but how indefinitely they may be below it, who can tell? If these facts are considered, the wonder is not that discrepancies exist, but that they are not vastly greater, especially if we bear in mind that in the case of Halley's comet the difference between the longest known period of revolution and the present shortest one is only twenty days short of five full years.

After this apology for astronomical calculations (and incidentally for ourselves!) we venture to make the following statements:

1. The comet will probably reach eighth magnitude about the middle of February. A good pair of field glasses ought then to show it in the western sky, approximately 44° east and 21° north of the sun's apparent place. As the comet will set about three hours after the sun, the advent of darkness may be awaited.

2. During the first third of March it may become possible to see the comet with the naked eye. But this can not last very long, since on March 16 it will set about half an hour after the sun, being some 5.5° north of it; whence it will be lost in the glow, unless very bright.

3. About March 23 sun and comet will be in superior conjunction, that is, as seen from the earth, both bodies will have the same right ascension, the comet being beyond the sun and about 5.5° north of it. Of course, there will be no possibility of seing the former, owing to the glare of the latter.

4. Toward the middle of April the comet may be looked for in the morning sky, where it will rise before the sun, being 2.5° south of the point of sunrise on April 15. It ought to be an easy object for the unaided eye. It will be noticed that, while in the west the comet appeared to plunge headlong toward the horizon, it is now backing into view, as the tail is always pointing away from the sun. For some five weeks the difference between the rising of the comet and sunrise will increase; but six days before inferior conjunction on May 19, it will again decrease until the comet is once more lost to view in the splendor of the sun shortly before conjunction.

5. According to the latest information on hand, the exact time of perihelion passage, or closest approach of the comet to the sun, is April 19.65 Greenwich time, which, in the ordinary way of counting dates, is 11 o'clock and 36 minutes a. m. of April 20, Insular time (one hundred and twentieth meridian east of Greenwich).

6. After perihelion the comet will approach the earth very rapidly

and, therefore, quickly increase in size until the time of inferior conjunction with the sun and shortest distance from the earth. At this time the *apparent* motion of the comet will be so swift that the latter will seem to pass through more than 45° in right ascension in the short space of four days.

7. Earth and comet will be in heliocentric conjunction at 10 a. m. of May 19 (Insular time). Messrs. Cowell and Crommelin, of Greenwich Observatory, have calculated that the comet, as seen from the earth, will pass across the sun's disk nearly centrally, entering from the west and accomplishing the transit in about one hour. Though the sun will then be high in heaven in this part of the world, there is very little hope that the comet can actually be seen on the sun's disk. According to all that we know of the nature of comets, even their nuclei are not dense enough to intercept the sun's rays sufficiently to reveal the comet's presence between the sun and the eye of the terrestrial onlooker.

8. If the present appearance of Halley's comet rivals the former, the comet will be a magnificent object. As to the probable length of its tail, nothing can be stated. The greatest length on record was 60° (in 1456); that is, two-thirds of the distance from the horizon to the zenith. How close to the sun the comet will be visible is likewise unknown. The great comet of 1882, for instance, was actually first discovered on the day of its perihelion passage, when only 2° from the sun.

9. While *before* conjunction the comet preceded the sun in the morning, it will follow the same *after* this event and, therefore, may again be observed in the evening. But it will rise rapidly in the sky, tail foremost, and fade away very quickly, since it now not only recedes from the sun, but also from the earth, comet and earth moving in almost opposite directions. Before the middle of June it will probably be lost to the naked eye; at the end of June field glasses will no longer show it; and at the end of July it will be invisible even in the largest telescopes. When, after about seventy-six years, Halley's comet will again appear to the eye of man, neither the writer of these lines, nor the vast majority of those for whom they are written, will gaze upon its weird but harmless beauty—for us the end of the visible world will have come.

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